
Incidence of rotary ProFile instrument fracture and the potential for bypassing *in vivo*

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Abstract

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Aim To determine the incidence of rotary ProFile instrument fracture and the potential for bypassing in molar teeth *in vivo*.

Methodology Four hundred and nineteen maxillary and mandibular first and second molars (1457 canals) were cleaned and shaped by two endodontists with new and used sets of nickel–titanium ProFile .04 taper rotary instruments. Each set of instruments was used in five molars and was steam-autoclaved before use. The canals were instrumented using passive instrumentation and a crown-down preparation technique. Instruments were examined both before and after use to evaluate whether breakage or deformation had

occurred. All canals were instrumented to at least a size 30 at the working length.

Results Nineteen instruments demonstrated visible signs of plastic deformation and were discarded and replaced, whilst 21 instruments underwent intracanal fracture during treatment. Amongst these, 14 fractured in the apical third, whilst the remaining seven fractured in the middle third. Seven instruments were bypassed, and treatment was completed. There was a significantly greater number of instrument fractures with the size 20 ProFile than with the other sizes, especially after the second time of use ($P < 0.05$).

Conclusions Prolonged clinical use of ProFile nickel–titanium instruments increased their fracture rate. One-third of fractured instruments were bypassed.

Keywords: nickel–titanium, ProFile, separation.

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Introduction

Various root-canal instruments and techniques have been proposed for cleaning and shaping the root-canal system. However, the creation of a continuously tapering conical form, thorough debridement, maintenance of the original shape and position of the root canal and apical foramen are still difficult, especially in curved canals (Schilder 1974). In addition, procedural accidents such as ledges, zips, perforations and instrument fracture are mishaps that occur while instrumenting curved canals.

Modified instruments and new techniques have been introduced to prevent or minimize such accidents. Recently, nickel–titanium instruments have played an

important role in root-canal preparation, particularly in curved roots. These instruments have gained popularity, and are routinely included in the current endodontic armamentarium. Indeed, rotary instruments have been shown to result in little or no canal transportation (Glosson *et al.* 1995, Knowles *et al.* 1996, Tharuni *et al.* 1996, Frick *et al.* 1997). Thus, these instruments offer possibilities for improving the speed and efficiency of root-canal treatment.

Because of limited experience, little is known about the limits and risks of rotary instrumentation or which is the most efficient means for using this new technology (Gambarini 2001). Although nickel–titanium instruments are reported to be stronger than stainless steel files (Walia *et al.* 1988), the fracture of nickel–titanium instruments within canals can occur as a result of rotational stress placed on engine-driven instruments. If an instrument tip becomes lodged and hand-piece rotation continues, instrument failure is probable. Removal of the fractured fragment may

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not be feasible and may jeopardize the outcome of treatment.

Nickel–titanium rotary instruments have been reported to undergo unexpected fracture without any visible defects of previous permanent deformation (Laustren *et al.* 1996, Pruett *et al.* 1997). Therefore, manufacturers state that the only predictable way to prevent fracture is to discard rotary instruments regularly after a certain number of uses, but there is no agreement or scientific evidence as to the exact number of cases that should be attempted.

The purpose of this study was to analyse the type and frequency of fracture of ProFile instruments, the ability to bypass them during routine clinical use in molar teeth, and to draw conclusions regarding the reasons for failure.

Materials and methods

Four hundred and nineteen maxillary and mandibular first and second molars (1457 canals) needing root-canal treatment in 408 patients, ranging in age from 15 to 45 years, were prepared by two endodontists trained in the ProFile technique over a 1-year period in the Endodontic Department, King Fahad National Guard Hospital, Riyadh, Saudi Arabia. The criteria for selection were working length more than 15 mm, canal curvature of approximately 30° and fully formed apices. Three pre-operative radiographs were taken for all teeth at a constant target-film distance and angulation by utilizing the extension cone paralleling device (Rinn Corp., Elgin, IL, USA): one with a 90° angulation to the tooth in a bucco-lingual direction and the other two at a mesial and distal angulation of approximately 20° to allow better visualization of the bucco-lingual anatomy. The radiographs were examined on a viewer using a peripheral block and a ×6 magnifying lens. The degrees of canal curvature were determined using the method of Schneider (1971) using the right-angled radiograph.

After access cavity preparation, the canals were located using an endodontic explorer, and the patency of the canals was explored with a size 10 K-file. Orifice enlargement of each canal was achieved using Gates Glidden burs (nos. 4, 3, 2 and 1). The working length was set 0.5 mm short of the canal length and was determined using a Root ZX electronic apex locator (J. Morita Corp., Kyoto, Japan), and then confirmed radiographically. The canals were instrumented to working length with size 15 K-type file after being dipped in RC Prep (Premier Dental Products Co., Philadelphia, PA, USA) before using rotary instruments. ProFile .04 taper nickel–

titanium instruments (Dentsply Tulsa Dental Products, Tulsa, OK, USA), sizes 40–20, were used in a crown-down technique. Each set of ProFile sizes 40–20 was used for shaping the canals of five molars before being discarded. The same set of ProFile instruments was sterilized before use in a steam autoclave (Model 2540; Tuttnauer USA, Ronkahoma, NY, USA) at 135 °C for 3 min; the entire sterilization cycle lasted 35 min. All teeth were instrumented with an Aseptico AEU-17BT electrical motor and hand-piece with contra angle 16 : 1 reduction, set at 260 r.p.m. During shaping, copious irrigation with 1 mL of 5.25% NaOCl was used between each instrument. The patency of the apical foramen was maintained by passing the tip of a size 10 K-file through the apical foramen after each use of the set of ProFile sizes 40–20. Each instrument was used in each canal after being dipped in RC Prep (Premier Dental Products Co., Philadelphia, PA, USA). Preparation was considered complete when at least a size 30 instrument achieved working length. After each use, instruments were wiped with isopropyl alcohol and inspected using ×2.5 magnification for signs of fracture and flute distortion. When irreversible deformation was noted prior to use, the instruments were discarded. In case of instrument fracture, an attempt was made to bypass the fractured segment using a size .08 and 10 K-file after loosening the debris around the fractured segment with sodium hypochlorite and EDTA. The solution was activated with a UTHA ultrasonic tip at the lowest power setting and the lightest touch. If the fractured segment could not be bypassed, the size and number of times the instrument had been used were recorded. All canals were filled using lateral condensation. Three postoperative radiographs using the same exposure geometry were taken to confirm canal configuration.

Data were statistically analysed using Chi-square tests. Statistical significance was established at $P < 0.05$.

Results

Out of the 419 maxillary (173) and mandibular (246) first and second molars, 19 instruments out of 449 (4.2%) demonstrated visible signs of plastic deformation, and were discarded and replaced (Table 1), whilst 21 instruments (4.6%) underwent intracanal fracture during treatment (Table 2). Fourteen instruments fractured in the apical third of which six were of size 20, three of size 25, three of size 30 and two of size 35. Amongst those, three were bypassed, and root-canal treatment was completed. The remaining seven instruments fractured in the middle third of which 2 were of size 40, three of size

Table 1 The number of ProFile file showed signs of deformation in 419 molars

Instrument size	Signs of deformation	Number of use
20	3	1–3
25	4	2–3
30	5	2–5
35	5	3–5
40	2	4–5
Total	19	–

Table 2 The number of the ProFile file separated in 419 molars

Instrument size	Apical third	Middle third	Number of use	Total
20	6	0	1–3	6
25	3	0	3–4	3
30	3	2	4–5	5
35	2	3	5	5
40	0	2	5	2
Total	14	7	–	21

35 and two of size 30. Four of the seven were bypassed, and treatment was completed to working length. The prolonged clinical use of nickel–titanium engine-driven instruments increased the incidence of fracture (Table 2). There was a significantly greater number of fractures noted in the size 20 instruments ($P < 0.05$).

Discussion

A major concern with the use of nickel–titanium rotary instruments is the possibility of unexpected fracture. Distortion and fracture occur in two ways: through torsional or flexural fatigue (Pruett *et al.* 1997, Sattapan *et al.* 2000). Torsional fracture results when the instrument exceeds the elastic limit of the metal, producing plastic deformation followed by fracture. This occurs when the tip or any part of the instrument binds in the canal and rotary motion continues. Flexural fracture occurs because of work hardening and metal fatigue. This happens at the point of canal curvature, when the instrument is freely rotating, and the instrument flexes until fracture occurs at the point of maximum flexure. Pruett *et al.* (1997) suggested that flexural fracture plays an important role in the fracture of nickel–titanium instruments clinically. Sattapan *et al.* (2000) found that 55.7% of the instruments failed from torsional fatigue and 44.3% from flexural fatigue. They concluded that because torsional failure occurred more frequently than flexural fatigue, a light touch without forcing an instrument apically should be used.

To prevent flexural fracture, a limited duration of use for each instrument should be observed, and instruments should be discarded after substantial use, regardless of whether any defects are visible (Pruett *et al.* 1997). However, no study or information is available to specify how many times rotary instruments can be used safely. Zuolo & Walton (1997) noticed that after prolonged experimental use (12 min in the mesial canals of extracted mandibular human molars), most instruments were considered to be unusable. Gambarini (2001) demonstrated that repeated clinical use (10 clinical cases) significantly reduced cyclic fatigue resistance of ProFile nickel–titanium instruments when compared with new ProFile instruments of the same size. Yared *et al.* (2000) evaluated cyclic fatigue of used nickel–titanium rotary instruments and stated that rotary instruments could be safely used in four molar cases. They found that clinical use did not lead to a decrease in the number of rotations to fracture of the instruments.

In the present study, 21 ProFile instruments fractured in the canals. This result is not in agreement with the study of Yared *et al.* (2000). The presence of intracanal instrument fracture compared to the previous study could be explained by the following facts. First, the sample size in this study was large (419 molars) compared to the previous study (52 molars). Second, instruments were used in five clinical cases compared to four clinical cases. Third, it is impossible to obtain exact measurements of canal curvatures from clinical radiographs. In bucco–lingual curvatures that exceed 30° or are abrupt, short radius curvatures may have been present, but could not be detected. Fourth, it is important to note that the tubular model system used in the previous study did not reproduce the same stresses on instruments as those encountered in root–canal preparation. Fifth, the different preparation sequence and the use of .04 instruments in this study.

Nineteen instruments showed visible signs of plastic deformation at their tips and were discarded. Most of these deformations occurred during the fourth and fifth clinical use for larger instruments (sizes 30, 35 and 40) and the second and third time of use for smaller instruments (sizes 20 and 25). This result was also noted in other studies (Yared *et al.* 2000, Gambarini 2001).

The smallest instrument (size 20) demonstrated the greatest number of fractures (almost one-third of the fractured instruments); this is probably because of the crown–down technique, where there is more engagement of the smaller instruments close to their tips. In the middle third, instrument binding is probably not occurring at the tip level, and this may explain why it

was often possible to bypass them (more than half of the fractured instruments could be bypassed in the middle third). It is also possible that this instrument was used in extremely tight and/or calcified canals where resistance to penetration was high and instruments were subjected to high-level torque. If torque is higher than the elastic limit of the instrument, plastic deformation and/or fracture can occur. If this .04 sequence is used, it may be prudent to view size 20 as a disposable instrument. This is also in agreement with a previous study (Yared *et al.* 1999), where it was found that size 20 instruments had a significantly higher number of rotations to breakage. Similarly, Gabel *et al.* (1999) demonstrated a higher incidence of failure with size 20/.04 ProFile and the smallest orifice shaper used in their study (size 40/.06 instrument) as compared with the other instruments. Excessive force was shown by Barbakow & Lutz (1997) to be the major cause of instrument fracture. The results of their study indicated that smaller instruments experienced a greater percentage of distortions than larger instruments, most likely because of lower resistance to torsional fracture. All distortions occurred near the tip of the instrument, as expected, because these instrument sizes were typically used for apical enlargement.

Conclusions

The results of the present study demonstrate that repeated clinical use of .04 ProFile nickel–titanium instruments significantly reduced their fracture resistance. Four out of the 7 instruments that fractured in the middle third were bypassed, whilst 3 out of the 14 instruments that fractured in the apical third were bypassed.

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